

HICKOK

MX-333

DIGITAL MULTIMETER

INSTRUCTION MANUAL

HICKOK

THE HICKOK ELECTRICAL INSTRUMENT COMPANY
10514 Dupont Avenue • Cleveland, Ohio 44108





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DIGITAL MULTIMETER
INSTRUCTION MANUAL

(STOCK NO. 2490-714)

The Hickok Electrical Instrument Company

10514 DUPONT AVENUE • CLEVELAND, OHIO 44108 • (216) 541-8060 • TWX: 810-421-8286

LIMITED WARRANTY

IMPORTANT

The following warranty shall be void if the registration card is not properly completed and returned to the Hickok factory, post marked within ten days after date of purchase.

The Hickok Electrical Instrument Co. warrants this instrument of its manufacture to be free from defects in material and workmanship for a period of one year (12 months) from the date of original purchase, subject to the following conditions.

Any instrument found to be defective during the first twelve month period after date of purchase may be returned, transportation prepaid, to the factory for repair or, at our option, replacement without charge.

This warranty does not apply to any of our products which have been repaired or altered by unauthorized persons, or which have been subject to misuse, negligence, or accident, or which have had the serial number altered, effaced, or removed. Neither shall the warranty apply where a warranty registration card has not been properly completed and returned to us promptly after purchase. This warranty is in lieu of all other warranties whether expressed or implied.

RETURNING EQUIPMENT FOR REPAIR

Before returning any equipment for service, the factory must first be contacted, giving the nature of the trouble. Instructions will then be given for either correcting the trouble or returning the equipment. Upon authorization, this equipment should be forwarded directly to:

Hickok Electrical Instrument Co.
1714 Carrollton Avenue
Greenwood, Mississippi 38930

or to a designated service station in your locality.

TABLE OF CONTENTS

SECTION		Page
I	GENERAL	1
II	SPECIFICATIONS	2
	DC Volts	2
	AC Volts	2
	Resistance	2
	Diode Test	3
	AC/DC Current	3
	Vari-Pitch	3
	Logi-Trak	3
	General	4
III	DESCRIPTION OF CONTROLS AND INDICATORS.	6
IV	OPERATING INSTRUCTIONS	9
	Digital Multimeter	9
	Battery Installation	9
	Belt Clip Installation	9
	Reading the Display	10
	Selecting Ranges and Functions	10
	Input Connections to COM Jack	11
	DC Volts Measurement	11
	AC Volts Measurement	11
	Ohms Measurement	11
	20 Ohms Range	13
	Testing Semiconductor Junctions	13
	DC Current Measurement	14
	10 Amp DC Current Measurement	14
	AC Current Measurement	14
	10 Amp AC Current Measurement	15
	Vari-Pitch Audio	15
	Logi-Trak	16
V	GETTING THE MOST OUT OF VARI-PITCH AND LOGI-TRAK	18
	Vari-Pitch	18
	Choosing the Proper Range	18
	Detecting Ripple or Noise on Power Supply Lines	18
	Locating Intermittent Problems	18
	Troubleshooting by Characteristic or "Signature" Sounds	19
	Capacitor Checking	19
	As An Analog Meter for Peaking and Nulling	19

TABLE OF CONTENTS (CONT)

SECTION		Page
	Logi-Trak	21
	Specific Logic Families	24
	Other Logic Families	26
	Signature Analysis	26
	Increasing Sensitivity	27
VI	CALIBRATION AND MAINTENANCE	28
	General	28
	Theory of Operation	28
	Analog-to-Digital Converter	28
	Vari-Pitch	32
	Logi-Trak	32
	Equipment Needed	32
	Disassembly	33
	Fire-Up	34
	DC Volts Cal	34
	AC Offset	34
	AC Cal	34
	200 Ω Cal	35
	20 Ω Cal	35
	Sound Adj	35
VII	CONVERSION TO RECHARGEABLE OPERATION .	36
VIII	ACCESSORIES	38
	Earphone (Model EP-1)	38
	Deluxe Carrying Case (Model CC-4)	38
	AC Adapter (Model RC-3 or RC-4)	39
	High Voltage Probe (Model VP-40)	39
	RF Voltmeter Probe (Model VP-14)	39
	Temperature Probe (TP-20C or TP-20F)	40
	10:1 Oscilloscope Probe (Model SP-7)	41
	Tachometer Adapter (TA-104)	41
IX	PARTS LIST	43

SECTION I GENERAL

The Hickok MX-333 Universal Digital Multimeter is one of the most sophisticated troubleshooting tools ever designed for the service and laboratory environment. It packs more measurement capability in a small 2.2" x 6.7" x 6", 22 oz. case than any electronic tool ever developed. The MX-333 is a full function 0.1% digital multimeter with extra capability such as the 20 ohm and 10 Amp ranges. The VARI-PITCH feature, a variable tone audio that works on all ranges and functions with virtually instantaneous response, is probably the highest efficiency troubleshooting tool ever developed for electronic service. The LOGI-TRAK input which uses the VARI-PITCH for fast "eyes off" indication exceeds speed and usefulness of even the most expensive digital logic probes. In addition, LOGI-TRAK has a multitude of uses in various types of electronic servicing other than digital logic.

The high impact case of the MX-333 is the most sensible case designed for LCD type readouts. The 45° angle readout catches the overhead light enabling optimum viewing of the light reflecting type LCD readout. In addition, the case styling can be used as conveniently on the bench as on your belt. The high impact case and suspended printed circuit board make the unit almost indestructible. The 6kV transient input protection on DC and AC, the no fuse 500V protection on ohms, and the fuse protection on current means the unit is nearly electrically immune to damage as well.

SECTION II SPECIFICATIONS

(all accuracies are for 1 year, 18° to 28° C)

<u>DC VOLTS</u>	200mV	2V	20V	200V	1000V		
Resolution	100μV	1mV	10mV	0.1V	1V		
Accuracy	±0.1% of reading + 1 digit						
Overload Protection	1000V DC/Peak AC + up to 6kV transients all ranges						
Input Impedance	10MΩ ±0.1% all ranges						
Rejection Ratios	NMRR: 60dB @ 60Hz: CMRR: 100dB						
<u>AC VOLTS</u>	200mV	2V	20V	200V	1000V		
Resolution	100μV	1mV	10mV	0.1V	1V		
Accuracy	±.75% of reading + 2 digits, 45Hz-500Hz (all ranges) ±2% of reading + 5 digits, 500Hz-5kHz (200mV to 20V ranges)						
Overload Protection	1000V DC/750Vrms all ranges except 200mV range 15 sec. above 200Vrms						
Input Impedance	10MΩ ±0.1% all ranges						
Blocking Voltage	1000V DC plus Peak AC						
<u>RESISTANCE</u>	20Ω	200Ω	2kΩ	20kΩ	200kΩ	2MΩ	20MΩ
Resolution	.01Ω	0.1Ω	1Ω	10Ω	100Ω	1kΩ	10kΩ
Accuracy	±3%	0.2%	0.1%	0.1%	0.1%	0.1%	1% + 1 digit
Overload Protection	500V DC/RMS on all ranges plus 2A fuse on 20Ω range						
Test Voltage	0.25V max at full scale, 3.2V max open circuit						

DIODE TEST 0 to 2V DC. Measures forward V drop of diode junction

Test Levels 2mA nominal; 2.5V max open circuit voltage

Overload Protection 500V DC or RMS

AC/DC CURRENT 2mA 20mA 200mA 2A 10A

Resolution 1 μ A 10 μ A 0.1mA 1mA 10mA

DC Accuracy $\pm 1\%$ $\pm 1\%$ $\pm 1\%$ $\pm 1.5\%$ $\pm 1.2\%$ + 1 digit

AC Accuracy $\pm 2.5\%$ $\pm 1.5\%$ $\pm 1.5\%$ $\pm 1.5\%$ $\pm 1.5\%$ + 2 digits
45Hz-400Hz

Voltage Burden 0.25V 0.25V 0.25V 0.25V 0.5V

Overload Protection All but 10A range fuse ** protected to 250V at 2A
10A range will accept 15A for 1 minute

VARI-PITCH * Operates on all ranges and functions

Tone Variable pitch proportionate to reading

Resistance "Off" at open circuit, tone begins at approx. full scale and increases frequency as resistance approaches "0" ohms

Other Functions "Off" at or near 0 and negative readings, tone begins at reading of 40 or less and extends to 4 times full scale

Open Leads Tone is off on all ranges and functions

Response Instantaneous (less than 100msec)

Activation On-Off button on front panel of MX-333

LOGI-TRAK * 0-20V (using Hickok SP-7 or other 10:1 scope probe)

Input Impedance 10M Ω shunted by approx. 10 pF

Minimum Pulse Width 5nsec typical, tested to 8nsec

*Patent Pending

** Fuse is accessible at rear panel

Pulse Indication	Sign on readout/distinctive audio signal
Maximum Frequency	80MHz
Memory/Thresholds	See LOGI-TRAK discussion
Resolution	10mV
Accuracy	$\pm 2\%$ of reading + 1 digit plus probe accuracy
Overload Protection	300V DC or RMS continuous

GENERAL

Display	3-1/2 Digit LCD (1999 count) Automatic Zero, Polarity, Decimal
Power	Single 9V battery (incl.) or optional AC adapter
Battery Life	Alkaline: 140 hrs. typical (See table below for more complete data)
Battery Indicator	"LO BAT" on display when approx. 20% life remains
Temperature	0° to 50°C operating: -25° to +60°C storage
Humidity	Up to 80% to 35°C: Up to 70% to 50°C
Temperature Coefficient	0° to 18°C, 28° to 50°C: 0.1 x appl. acc. spec./°C
Shock and Vibration	Meets MIL-T-28800 specifications
Maximum COM Mode V	500V DC
Dimensions	2.2 x 6.7 x 6 in. (5.6 x 17 x 15.2cm)
Weight	22 oz. (.7kg)
Includes	Deluxe Safety Test Leads, Battery, Instruction Manual, Belt Clip

ALKALINE BATTERY LIFE FOR VARIOUS FUNCTIONS

Function	Total Current Draw (typ)	Life to LO BAT (typ)	Additional Life after LO BAT	Remarks
Normal	2.6mA	140 hrs.	29 hrs.	20 ohm range draws additional 10mA continuously
Vari-Pitch				Figures in brackets assume low duty cycle usage (10%) typical of most normal applications
—quiet	5.9mA	64 hrs.	13 hrs.	
—continuous tone	12mA (6.6mA)	31 hrs. (57 hrs.)	6 hrs. (11 hrs.)	
Logi-Trak	5.3mA	71 hrs.	14 hrs.	Current draw is constant
Logi-Trak w/ Vari-Pitch				Figures in brackets assume low duty cycle usage (10%) typical of most normal applications
—quiet	8.5mA			
—continuous tone	14mA (9.5mA)	27 hrs. (40 hrs.)	5 hrs. (8 hrs.)	

SECTION III

DESCRIPTION OF CONTROLS

AND INDICATORS

Refer to Figure 1.

	Item Number	
V, Ω jack	1	A safety designed banana jack used as the positive (high) input when measuring DC volts, AC volts, resistance (except 20 ohm range), and diode test.
COM jack	2	A safety designed banana jack used as the common (low) input for all measurements.
mA jack	3	A safety designed banana jack used as the positive (high) input when measuring DC current, AC current, or using the 20 ohm resistance range.
10A jack	4	A safety designed banana jack used as the positive (high) input when measuring either DC or AC current on the 10 Ampere range.
POWER switch	5	A push-on, push-off switch used to turn the unit on and off.
DC switch	6	A pushbutton function switch used for measuring DC volts (200mV through 1000V ranges) or DC current (2mA through 10A ranges).
AC switch	7	A pushbutton function switch used for measuring AC volts (200mVrms through 750Vrms ranges) or AC current (2mA rms through 10A rms ranges).
OHMS switch	8	A pushbutton function switch used for measuring resistance (200 ohm through 20M ohm ranges).

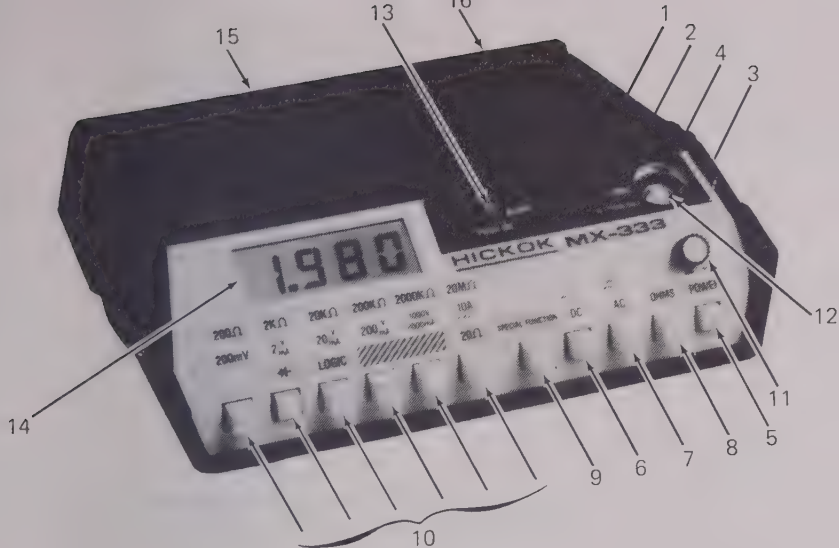


Figure 1. MX-333 Digital Multimeter

	Item Number	
SPECIAL FUNCTION switch	9	A pushbutton function switch used in conjunction with the range switches to implement a semiconductor junction test, digital logic probe operation or 20 ohm resistance range.
Range switches	10	Pushbuttons used to select a desired measurement range for DC volts, AC volts, DC current, AC current, resistance, or one of the special functions.
20Ω null control	11	Control used to null out test lead resistances. Active on 20 ohm resistance range only. Inactive on all other resistance ranges.
LOGIC input	12	A recessed, detented, safety designed bnc connector for use with 10:1 oscilloscope probe. Functions as a digital logic probe when SPECIAL FUNCTION and LOGIC switches are selected.

	Item Number	
AUDIO switch	13	A push-on, push-off switch used to activate VARI-PITCH sound circuitry.
Display	14	A 3-1/2 digit (1999 max) liquid crystal display incorporating decimal points, polarity indicator, and low battery annunciator. Used to indicate measured input values.
Battery compartment	15	Location of 9 volt transistor radio battery used to power unit. Also location of 2 Amp fuse used for protection of 20 Ω range and all current ranges (except 10A).
AC adapter input	16	Recessed connector for use with Hickok Model RC-3 (USA) or RC-4 (Europe) AC adapters.

SECTION IV

OPERATING INSTRUCTIONS

DIGITAL MULTIMETER

When received, the MX-333 shipping carton should contain the items listed below:

- 1 MX-333 Multimeter
- 1 MX-333 Instruction Manual
- 1 9 Volt Battery
- 1 Set of Safety Test Leads (red and black)
- 1 Black Alligator Clip
- 1 Belt Clip
- 1 Screw (for belt clip installation)
- 4 Rubber Feet (for use with belt clip - see BELT CLIP INSTALLATION)

Inspect each of these items as you remove them from the carton. We suggest you retain your carton in case future shipping of the unit is required.

BATTERY INSTALLATION

WARNING

To avoid electric shock, remove test leads from input terminal before opening the battery compartment.

To install the battery, locate the battery compartment on the rear panel of the unit. Unscrew the fastener on the left hand side of the battery compartment door. Swing the door off to the side to expose the battery clip. Extend the clip and cable from its compartment and attach the 9 volt battery supplied with the unit. Carefully position the battery into the battery compartment with the battery clip towards the center of the rear panel. Swing the battery compartment door back in place and reinsert the fastener. Do not overtighten the fastener.

Always use a good quality battery. Never leave a weak or dead battery in the unit since chemicals can leak out causing permanent damage to the instrument and voiding the warranty. The unit must be modified if rechargeable battery operation is desired. See CONVERSION TO RECHARGEABLE OPERATION, Section VII.

BELT CLIP INSTALLATION

The unit may be outfitted with a belt clip so that it may be conveniently carried on the waist for field use. To install the clip, turn the unit upside

down and locate the threaded insert centrally located in the bottom cover. Attach the belt clip with the screw provided, positioning the clip so that the open end faces the rear of the unit.

The four additional rubber feet provided with the instrument may be attached to the bottom on all four corners so that the unit will sit flat on a surface when the belt clip is attached. The feet are affixed with pressure sensitive adhesive. Peel off the protective paper, then press into place.

READING THE DISPLAY

The decimal point on the readout will be properly positioned for the range and function selected.

Polarity of DC voltages and currents are shown by a minus sign which indicates the input signal is negative with respect to the **COM** jack. Positive inputs are indicated by the absence of the minus sign.

Over-range is indicated by showing a "1" followed by three blanked (missing) digits []. For a negative input causing the over-range condition, the minus sign will be lit also.

A "LO BAT" annunciator will appear in the upper left hand corner of the display when the battery powering the unit uses up about 85% of its life. This indicates the battery should be replaced.

The liquid crystal display used in the instrument is rugged and long lived, but it can be affected by temperature extremes. Very cold temperatures can cause the numbers to become sluggish, while very hot temperatures (caused by extended exposure to bright sunlight, for example) may cause the entire display to temporarily turn black. In either case, the display will recover at normal operating temperatures.

SELECTING RANGES AND FUNCTIONS

The ranges are color coded for each measurement function. The ohms ranges are shown in green, the DC or AC ranges are shown in yellow, and the special functions are shown in blue.

The **DC** button selects both DC volts and DC current depending upon whether the test leads are connected to the **V,Ω** and **COM** jacks or the **mA** and **COM** jacks. Similarly, the **AC** button is used for both AC volts and AC current, depending upon which side panel jacks are used.

Most ranges and functions use the **V,Ω** and **COM** jacks. The 10 Ampere range (either DC or AC) use a separate jack. A third jack is used for the rest of the current ranges as well as the 20 ohm range. The LOGIC function uses the front panel **LOGIC** input only.

INPUT CONNECTIONS TO COM JACK

WARNING

*To avoid electric shock and/or instrument damage, do not connect the **COM** (common) jack to a source of more than 500 volts DC or DC plus peak AC above earth ground.*

DC VOLTS MEASUREMENT

To measure DC volts, plug the safety designed test lead set into the side panel jacks marked **V,Ω** and **COM**. Press the front panel **DC** switch and select the range marked in yellow that you expect to be appropriate for the measurements to be made. If a completely unknown voltage is to be measured, select the highest range (**1000V**) and then switch to lower ranges as required to obtain a three or four digit reading. Voltages up to 40kV DC may be measured with the Hickok VP-40 High Voltage Probe accessory. Refer to page 39 for details.

AC VOLTS MEASUREMENT

Plug the safety test lead set into the side panel jacks marked **V,Ω** and **COM**. Press the button marked **AC** on the front panel. Select the range marked in yellow that you expect to be appropriate for the reading you are to make. If a completely unknown voltage is to be measured, select the highest range (**750Vrms**) and then switch to lower ranges as required to obtain a three or four digit reading.

The AC ranges of the instrument use an average responding AC converter. This means the unit measures the average value of the AC signal. The unit is appropriately calibrated to display the RMS value of the AC signal. This type of system is accurate for sinewave signals. It may be inaccurate for other shapes of signals. Figure 2 is a chart indicating the conversion multipliers for non-sinusoidal signals. Because of the harmonic content of these waveforms, the upper limit of input frequency is less than that for sinewave inputs.

OHMS MEASUREMENT

Connect the test lead set to the **V,Ω** and **COM** jacks. Press the front panel button marked **OHMS** and select the appropriate range for the expected reading. Connect the test prods to the resistance to be measured. If the readout reads less than 3 full digits, select the next lower scale. If the readout remains over-ranged (showing a 1 and three missing digits) 1 , select the next higher scale.

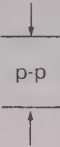
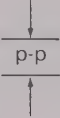
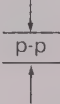
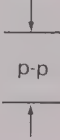
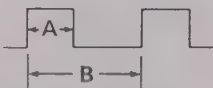
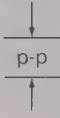
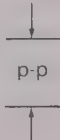
		Display Multiplier for Conversion to:		
INPUT WAVEFORM		Peak-to-Peak	RMS	Average
 Sine		2.83	1.00	0.90
 Full Wave Rectified Sine		1.41	1.00	0.90
 Half Wave Rectified Sine		2.83	1.41	0.90
 Square		1.80	0.90	0.90
 Rectangular Pulse		$0.9B/A$	$\sqrt{0.9A/B}$	$0.9A/B$
 Triangle		3.60	1.04	0.90

Figure 2. Conversion Multiplier for Non-Sinusoidal Waveforms

All the ohms ranges on the Model-333 are low power ohms. Low power ohms means the output voltage for an on scale ohms reading (1999 or less) is lower than the voltage that would normally turn on silicon diode junctions. This feature allows measurements of ohmic values to be made in circuit. A separate diode function is provided to check diodes.

When measuring ohms it is good practice on the initial tests to make a measurement, then reverse the test prods. The readings should be the same within a digit or two. If the readings vary by more than this, it is likely there are either semi-conductors in circuit which are affecting the reading or there may be voltage present in the circuit. In either case, accurate ohmic readings cannot be made until the cause of the reading difference is eliminated.

The Model-333 ohms ranges are protected up to 500 volts DC or DC plus the peak AC. If an accidental overload occurs, allow the protection circuits within the unit a minute or so to recover before making further measurements.

Note that when the test leads are shorted together and the 200 ohm range is selected, the display will typically read .2 or .3 ohms. This is due to test lead resistance. Subtract lead resistance from 200 ohm range readings, or connect the resistor directly across the **V, Ω** and **COM** jacks.

20 OHMS RANGE

Plug the safety designed test lead set into the **mA** (also marked **20 Ω**) and **COM** jacks located on the side panel. Select the **SPECIAL FUNCTION** button and the **20 Ω** button, marked in blue. Short the test prods together and adjust the **20 Ω** null knob, located on the right hand side of the panel, for a reading of 000. Connect the test prods to the circuit to be measured. Because this range can resolve 10 milliohms of resistance, it is important that good contact be made to the resistance being measured. Contact resistance, if not kept to a minimum, can become a significant error factor in the measurement.

The **20 Ω** range is fuse protected against accidentally applied overloads. If the display indicates over-range (showing a 1 and three missing digits) when the test leads are shorted together, the protection fuse may have been blown. This fuse is located on the top of the battery clip in the battery compartment. Replace it only with a 2 Ampere, fast acting fuse type 8AG or AGX.

WARNING

To avoid electric shock, remove test leads from input terminals before opening battery compartment.

TESTING SEMICONDUCTOR JUNCTIONS

Diode and transistor junctions may be checked by connecting the safety designed test lead set into the **V, Ω** and **COM** jacks, and selecting the **SPECIAL FUNCTION** and **→|—** buttons, marked in blue.

The **V,Ω** jack is positive with respect to the **COM** jack. The open circuit voltage is nominally 3 volts with a 2mA test current.

A reversed biased junction, or an open circuit, will cause the display to over-range (showing a 1 and three missing digits) **1.000**. A forward biased condition will cause the display to indicate the forward voltage drop of the junction with 2mA test current. Typically, silicon junctions read **.500** to **.700** and germanium junctions read **.300** to **.350**.

DC CURRENT MEASUREMENT

Plug the safety designed test lead set into the **mA** and **COM** jacks located on the side panel. Select the **DC** button and the **2000mA** range. If the reading is less than 3 full digits, select the next lower range. If the reading is zero, the current protection fuse located on the top of the battery clip in the battery compartment may have been blown. In the event that the fuse has been blown, replace it only with a 2 Ampere, fast acting fuse type 8AG or AGX.

WARNING

To avoid electric shock, remove test leads from input terminals before opening battery compartment.

10 AMP DC CURRENT MEASUREMENT

To measure up to 10 amps DC current, plug the safety designed test lead set into the **10A** and **COM** jacks located on the side panel. Select the **DC** button and the **10A** range marked in yellow.

WARNING

*The **10A** range is not fuse protected. Exceeding the maximum input current rating can cause instrument damage and/or operator hazard.*

AC CURRENT MEASUREMENT

Plug the safety designed test lead set into the **mA** and **COM** jacks located on the side panel. Select the **AC** button and the **2000mA** range. If the reading is less than 3 full digits, select the next lower range. If the reading is zero, the current protection fuse located on the top of the battery clip in the battery compartment may have been blown. In the event that the fuse has been blown, replace it only with a 2 Ampere, fast acting fuse type 8AG or AGX.

WARNING

To avoid electric shock, remove test leads from input terminals before opening battery compartment.

10 AMP AC CURRENT MEASUREMENT

To measure up to 10 amps AC current, plug the safety designed test lead set into the **10A** and **COM** jacks located on the side panel. Select the **AC** button and the **10A** range marked in yellow.

WARNING

*The **10A** range is not fuse protected. Exceeding the maximum input current rating can cause instrument damage and/or operator hazard.*

VARI-PITCH AUDIO

VARI-PITCH Audio is an analog audio signal that can be turned on or off utilizing the **AUDIO** button located in the upper center of the front panel. The sound exits from the small opening to the right of the **AUDIO** button. In order to turn the audio on, simply push the button until it latches. To turn the audio off, press the button again and it will unlatch.

The audio tone on the MX-333 changes frequency proportionate to the reading. When enabled, the VARI-PITCH Audio operates on all ranges and functions of the MX-333. The VARI-PITCH Audio has been designed to be nearly instantly responding on practically all ranges. It has also been designed to maximize the human ears ability to distinguish pitches in the primary areas of reading with your Digital Multimeter.

The audio response changes characteristics depending on the function where it is used. In DC volts, AC volts, DC current, AC current, and LOGIC, the audio will be silent for readings from $\boxed{000}$ to approximately $\boxed{030}$. The audio will also be silent for readings which are negative. On the ohms ranges, the audio is inverted so that when the readings are in over-range (1 and three missing digits) $\boxed{i\ \ \ \ }$, the audio is silent. When an on scale reading is obtained, the audio will increase in frequency as the reading decreases, up to a maximum frequency at, or near $\boxed{000}$. On the diode $\rightarrow|$ and 20 ohm ranges, the audio slope has been inverted so that with open test leads there is a high frequency tone supplied by the VARI-PITCH. Only on these two ranges will there be an audio tone when the test leads are not connected.

The audio slope is inverted on the 20 ohm range so that the human ear can best differentiate between the tones associated with the low resistance values (below five ohms) likely to be measured with this range. Both the 20 ohm and the diode ranges draw the most battery current of all the functions of the MX-333. Therefore, to maximize battery life, these ranges should be left in operation only when they are being used. The inverted audio response is an additional reminder to go to some other function or range when not using either of these functions.

Using VARI-PITCH on DC Volts, AC Volts, DC Current, AC Current

To use the VARI-PITCH Audio on DC volts, AC volts, DC current, and AC current ranges, simply connect the test leads and select the appropriate range as described in the DMM Section of this Operating Manual. Push the **AUDIO** button until it latches. You are now ready to make measurements that will also have an audio tone which is proportional to the display reading.

The VARI-PITCH Audio provides maximum audio resolution for readings on the Digital Multimeter from **000** to **500**. It is best to select the range that will present most of your readings in a range of **000** to **500**. Connect your test leads as you would to make any one of the measurements. The audio will respond nearly instantly.

Using VARI-PITCH on OHMS

To use the VARI-PITCH Audio on the ohms ranges, select the **OHMS** button and connect the test leads to the **V,Ω** and **COM** jacks. Push the **AUDIO** button until it latches. You are now ready to make measurements or continuity checks that will also have an audio tone which is proportional to the display reading.

The audio will be at its highest frequency for a reading of **000**. As the readings increase, the audio pitch will decrease, until becoming silent somewhere above **1999**, that is, when the display indicates over-range (**1**).

LOGI-TRAK

The LOGI-TRAK function is a built-in logic testing capability that works in conjunction with VARI-PITCH to provide rapid troubleshooting of logic circuitry.

To use, take any 10:1, 80MHz, or better oscilloscope probe (such as a Hickok SP-7), and plug it into the **LOGIC** input located in the upper right hand corner of the front panel. The **LOGIC** input is a recessed, safety designed bnc connector with a ball detent to hold the probe. No twisting is necessary. Just push to insert probe and pull to remove. Select the **SPECIAL FUNCTION** switch and push the **LOGIC** button.

WARNING

*To avoid the possibility of electric shock and/or instrument damage, unplug the oscilloscope probe from the **LOGIC** input when not using the LOGIC function.*

In the LOGIC mode, the display will read any DC voltage present at the probe tip from 10mV to 19.99 volts. The ground clip of the oscilloscope

probe must be connected to the ground of the circuitry under test. If the ability to detect fast pulses is not required, the ground connection may be made with a test lead between the MX-333 **COM** jack and the common of the circuit under test.

Use the oscilloscope probe to test various circuit points. Circuit disturbance is minimal due to the high input impedance and low capacitance of the probe. The presence of a logical "HIGH" or "LOW" as well as opens, floating inputs or shorts to either ground or power supply are readily identified by reading the display voltage and being familiar with the type of logic family being tested. Individual pulses, pulse trains, or level changes are indicated by the appearance of a colon in the middle of the display right above the decimal point. Any such edge change will blink the colon for about 0.1 seconds. If the activity occurs rapidly, the colon will appear to be on continuously. The display reading will indicate the average DC level of the pulse activity. For example, a squarewave coming from a CMOS I.C. running on a 5 volt supply would make the display read 2.50 volts, with the colon appearing also.

LOGI-TRAK becomes especially useful when VARI-PITCH is engaged. Since the audio pitch is proportional to the display reading, rapid eyes-off use of LOGIC-TRAK is possible merely by listening for the sounds associated with the various logic states or fault conditions. Pulse activity is identified by a characteristic chirping sound which is on whenever the colon is displayed.

SECTION V

GETTING THE MOST OUT OF VARI-PITCH AND LOGI-TRAK

VARI-PITCH

The variable pitch audible output response operates on all ranges and functions of the MX-333. This section is intended to present the more common uses of VARI-PITCH. Additional applications and techniques can readily be developed by the user once he is familiar with the feature.

CHOOSING THE PROPER RANGE

VARI-PITCH is designed to operate differently depending on the function being used. The audio response of the circuit is designed to have maximum audible pitch change at readings between **020** and **500** on the display. The audio *DOES* change frequency for readings above **500**, however, the rate of change is considerably slower. When making measurement it is advisable to select a range that will cause most of the readings to be in the range of **020** to **500**. As an example, consider tracing a 115V AC power line in a system to verify that the 115 volts is arriving at all its expected locations. Use the 1000 volts DC range to give you a nominal reading of **115**. This will also have an associated tone. Under these conditions, your ear will readily detect voltage changes as little as 2 volts from the nominal 115 volts.

DETECTING RIPPLE OR NOISE ON POWER SUPPLY LINES

VARI-PITCH as a troubleshooting tool can be extremely valuable when measuring DC volts in a variety of circuits. Particularly in power supplies where a ripple may be of some concern. If the ripple becomes significant, say more than 2% of the DC voltage, and the DC voltage reading is in **020** to **500** range, a 60 cycle warble will begin to appear. This is a good indication that there is a substantial amount of ripple on the supply and probably should be tested using AC voltage ranges to make an accurate measurement of the ripple.

LOCATING INTERMITTENT PROBLEMS

VARI-PITCH is designed for quick response. For this reason it can be a very useful tool when looking for an intermittent either in voltage or ohms. For example, consider a situation in which you are attempting to find intermittent continuity somewhere in a system. Set the MX-333 to the **200 ohms**

range and connect it between the two suspected points. VARI-PITCH will present a tone associated with the impedance between the two points. Then move wires, vibrate, and otherwise attempt to make the intermittent occur. A change or interruption of audio tone will instantly alert you if there is, in fact, an intermittent connection. The fast response of the VARI-PITCH output allows you to detect intermittence that would not be detected with an ordinary digital or analog meter.

TROUBLESHOOTING BY CHARACTERISTIC OR "SIGNATURE" SOUNDS

In repetitive troubleshooting or similar systems, certain signals will often produce characteristic and distinctive sounds from the VARI-PITCH output, depending on the frequency and amplitudes associated with the signal. Once these characteristic sounds are learned, troubleshooting of many circuits can be performed by simply touching the probe to the various points and listening to see if the characteristic sounds are there. The human ear is particularly adept at noticing the differences in sound which will occur as signals change. It is fortunate that the human ear is particularly sensitive to small changes of a frequency and is particularly sensitive to harmonics added to a base frequency. For these reasons the VARI-PITCH can be an extremely useful tool for detecting small differences in reading or characteristic sounds associated with particular signals. In many of these cases the VARI-PITCH allows the MX-333 to replace a variety of additional test equipment including an oscilloscope in many applications.

CAPACITOR CHECKING

VARI-PITCH can be used for detection of capacitors in circuits. When there are capacitors present, there will be time associated with charging of the capacitors. It is possible to approximate the value of the capacitor by counting the seconds that it takes to charge the capacitor until the sound stops changing and noting the final resistance reading.

AS AN ANALOG METER FOR PEAKING AND NULLING

The VARI-PITCH output of the MX-333 provides an analog response similar to an analog meter. An analog response is often more suitable than a digital reading for detecting trends (increasing or decreasing) in measurements. The VARI-PITCH analog response fills this need for trend indication in a variety of adjustment applications. For example, consider making a calibration adjustment which calls for adjusting to maximum voltage. Using the appropriate voltage range with VARI-PITCH, simply adjust for the highest frequency tone. Typical adjustments of this type can be achieved within 1/2% of the true peak voltage very quickly with VARI-PITCH.

ADDITIONAL VARI-PITCH APPLICATIONS

This has been a brief sampling of ways to use VARI-PITCH to advantage. There are many more ways, there simply isn't room to describe.

AC

- Distinguish between 60Hz and 400Hz line
- Trace 100 to 400Hz audio through audio circuits
- Trace line voltages
- Distinguish between 110 and 220V AC
- Detect operation of line chopper circuits
- Detect full wave vs half wave rectification
- Check SCR control outputs

DC

- Detect 2% ripple on power supply
- Check power bus voltages
- Use for peaking or nulling
- Monitor pulse width modulated circuits
- Identify voltage polarity
- Check AGC circuit operation
- Detect low frequency instabilities in amplifiers (motor boating)
- Check power supply regulations
- Check power supply transient response

OHMS

- Fast continuity check - Test cables, point to point connections, chassis inter-connects, ground connections, coax wiring
- Detect faulty connections
- Check pots for wiper contact over full travel
- Remote contact closure detections
- Check potentiometer taper
- Check for motor brush bounce

General

- Detect intermittents on volts, ohms, or current by listening for audio discontinuities
- Use an annunciator - monitor relays for closure, etc. Audio will appear "A-B" comparisons when troubleshooting between good and bad units
- Signature sound analysis of test points

Diode Check

- Eyes off go-no go diode check
- Distinguish between silicon and germanium (or Schottky) semiconductor junctions
- Check LED's, infra-red emitters, and optical coupler inputs

LOGI-TRAK

The LOGI-TRAK function is a built-in logic testing capability that works in conjunction with VARI-PITCH to provide rapid troubleshooting of logic circuitry.

To use, take any 10:1, 80MHz, or better oscilloscope probe (such as a Hickok SP-7), and plug it into the **LOGIC** input located in the upper right hand corner of the front panel. The **LOGIC** input is a recessed, safety designed bnc connector with a ball detent to hold the plug. No twisting is necessary. Just push to insert probe and pull to remove. Select the **SPECIAL FUNCTION** switch, push the **LOGIC** button, and push the **AUDIO** button on.

WARNING

To avoid the possibility of electric shock, unplug the 10:1 probe from the front panel when not using the LOGIC function.

In the LOGIC mode, all measurements are made using the 10:1 probe which forms a combination 80MHz logic probe and digital voltmeter, without any further switching. Connect the ground clip of the 10:1 probe to the ground or common of the circuit under test and begin testing. Alternatively the ground connection may be made with the normal black test lead connected between the **COM** jack of the MX-333 and the circuit ground, if high frequency pulse detection is not required. The 10:1 probe, through the **LOGIC** input can be used as a voltmeter and/or as a logic probe separately or simultaneously.

As a Voltmeter

In the LOGIC mode, using the 10:1 probe, the display will indicate any DC voltage from 0.01 to 19.99 volts. Even though a 10:1 probe is used, the display is a direct indication and no mental multiplication is required. The decimal point is correctly located and the 10:1 divide is automatically taken into account when LOGIC mode is selected and the **LOGIC** input is used. Any voltage up to 19.99 volts positive or negative can be measured although, of course, the sound will be off for negative voltages. Although the use of the LOGIC mode for voltage measurement is primarily designed for use in logic testing applications, there are some advantages for other applications as well as a few cautions to be observed.

Using the 10:1 probe maintains the normal 10 Megohm input impedance but also provides decreased capacitive loading on the circuit being measured because of the low capacitance (12 pF max) of the probe. This can be especially useful when measuring DC voltages in capacitance sensitive circuits such as oscillators and tuned amplifiers. DC voltages can be measured

with the 10:1 probe through the **LOGIC** input **ONLY** on the **LOGIC** range and **ONLY** when the **SPECIAL FUNCTION** button is pressed. The 10:1 **LOGIC** input is disabled for all other ranges and functions.

The user should be aware that the use of the 10:1 **LOGIC** input usually results in less accuracy (typically 1%) than the basic 0.1% accuracy of the MX-333 in proportion to the inaccuracy of the particular 10:1 probe used. The degree of error added by the use of the 10:1 probe can be readily checked as follows: First measure some stable voltage with the normal input and leads using the 20V DC range and note the reading. Then measure the same voltage using the 10:1 probe through the **LOGIC** input. Calculate the percentage error of the second reading. In most instances the error percentage will be negligible compared to the accuracy required, but if not, the readings can be corrected by the known percentage to achieve greater precision.

The user should also be aware that the maximum input voltage at the **LOGIC** input is 30V. (This corresponds to 300V at the tip of the 10:1 probe.) If voltages over 300V are likely to be encountered, even accidentally, the standard input and leads should be used.

As a **LOGIC** Probe

The MX-333 LOGI-TRAK system, like a standard logic probe, allows the user to detect logical high and low states as well as pulse activity in digital systems. Unlike a standard logic probe, however, LOGI-TRAK can detect marginal or out of spec logic operation, perform simple signature analysis, and be compatible with any existing or future logic family running off at 20 volt or less power supply. These techniques will be discussed shortly.

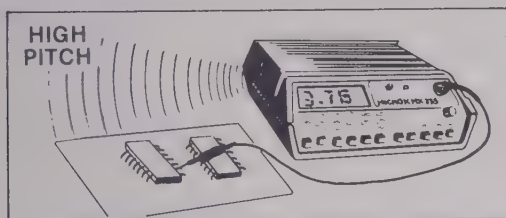
As noted at the beginning of this section, select the **SPECIAL FUNCTION**, **LOGIC**, and **AUDIO** buttons, then take a quality 10:1 oscilloscope, such as a Hickok 100MHz Model SP-7, and attach it to the safety designed, recessed bnc connector on the front panel. Push the probe connector into the front panel without twisting or turning. A detent mechanism will hold the probe cable in place. A gentle pull will detach the probe when required.

WARNING

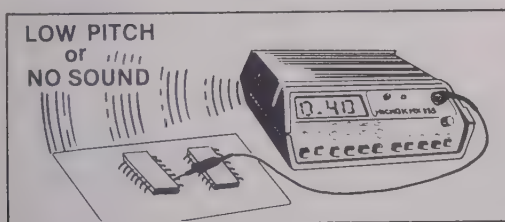
*To avoid electric shock, remove 10:1 probe from front panel when not using **LOGIC** function.*

Connect the probe ground clip to the digital logic power supply ground. If detection of fast pulses is not required, a test lead connecting the digital logic power supply ground to the MX-333 **COM** jack may be used in lieu of the probe ground clip. There should be no connections to the **V,Ω** jack, nor to the **mA** and **10A** jacks.

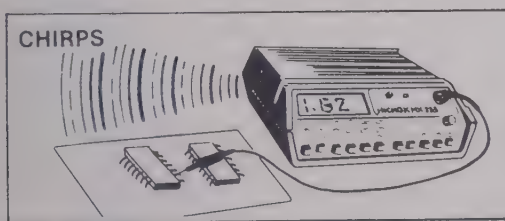
The probe impedance is 10 Megohms, shunted by about 10 picofarads. Thus, the loading it presents to the logic circuits being tested is almost negligible. In addition, the probe overload characteristics allow it to accidentally contact up to 300 volts DC plus peak AC, without damage.



Detecting a Logical HIGH: Touch probe to desired test point. The presence of a logical HIGH will be signaled by a high pitch audio tone. (The display will read out the logical HIGH voltage level.)



Detecting a Logical LOW: Touch probe to desired test point. The presence of a logical LOW will be signaled by either a low frequency sound, or no sound at all depending on how low the actual voltage is. (The display will read out the logical LOW voltage level.)

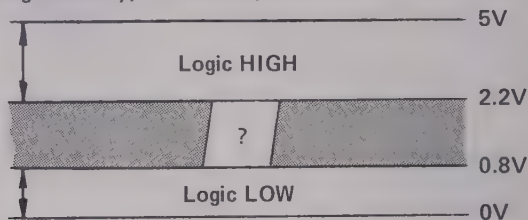


Detecting Logic PULSES: Touch probe to desired test point. A transition or pulses will produce a distinctive "chirp" sound in addition to the pitch associated with the basic logic level. The colon on the display (extra two dots above the decimal point) **0:00** will also flash for approximately a tenth of a second, providing a visual indication of a pulse or transition. Repetitive pulses or transitions will cause continuous "chirping" and the colon will appear to be lit continuously for pulse rates of 10Hz or faster. Pulses as narrow as 5nsec (typically) and at repetition ranges up to 80MHz are detected and indicated.

SPECIFIC LOGIC FAMILIES

LOGI-TRAK does much more than detect logical HIGHS, LOWs, and PULSES. It can alert the user to marginal or out of spec operation and catastrophic failures, once the user gains familiarity with logic family voltage levels involved. The following details on various logic families will be helpful in learning these characteristics.

TTL (Including Schottky, Low Power, etc.)



TTL Logic Levels

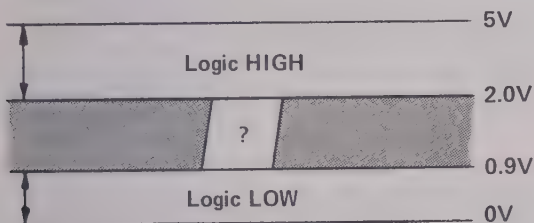
Logic states in TTL are defined according to their voltage level, as shown in the accompanying illustration. Voltages below 0.8 volts are always considered LOW, while voltages above 2.2 volts are always HIGH. In between voltages are indeterminate, i.e., one cannot tell if the logic will accept it as a HIGH level or a LOW level.

Just a few minutes practice will enable the user to determine, by tone, legitimate logic LOWs (0.8V and lower), and logic HIGHs (2.2V and higher), using the digital display for verification until the tones are readily recognized. In actual practice, logic LOWs and HIGHs are even easier to detect because typical voltage levels are much narrower than the specified levels. Most TTL LOWs are between 0.2 and 0.3V, and most TTL HIGHs are between 3.3 and 3.5V. The user will quickly learn to recognize the tones associated with these typical LOW and HIGH levels in actual use.

Once the user becomes familiar with the sound of the typical or normal HIGH or LOW, he can begin to recognize marginal, faulty, or suspicious levels by variances from the normal tones. For example, if a HIGH does not sound right, a quick glance at the MX-333 display will reveal what the voltage level actually is. A reading of 1.7 volts, say, is characteristic of an unconnected (*FLOATING*) gate *INPUT*. It could also mean that a faulty i.c. package is evident, or an external cause (like a short) is present requiring further attention. Similarly, an extra high pitch would alert the user to check the display and find a reading of 5.0 volts. This could indicate a *SHORT* to the supply rail. Some TTL circuits have resistor pull-ups to supply yielding HIGHs close to supply voltage. This would then be a normal condition, but usually the circuit diagram or device type would indicate if such passive pull-ups were used.

Conversely, an odd tone may indicate *MARGINAL* operation. For example, say the display reads out a LOW as 0.8 volts. While this is within the limits of normal operation, it is indicative of a possible circuit abnormality or an i.c. that may prematurely fail. Also, the circuitry is likely to be more noise sensitive. The difference between a *GROUND SHORT* (0V) and a normal LOW (0.2V) is usually detectable only by checking the digital display but the sound circuit can be made more sensitive if desired. (See *INCREASING SENSITIVITY* below.)

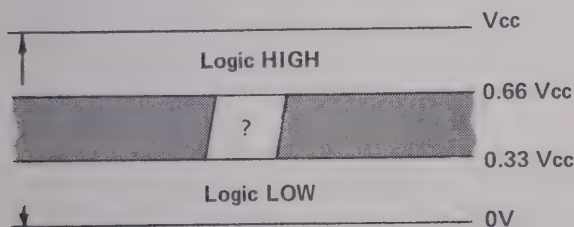
DTL



DTL Logic Levels

Voltage levels for DTL logic states are shown in the accompanying diagram. The input characteristics of DTL are similar to TTL, but DTL outputs have internal pull-up resistors to supply. Thus, output levels for a logic HIGH will be 4 volts or higher, depending on loading. Listening to a known logic level with *VARI-PITCH* will provide a reference pitch easily remembered. Encountering faulty or marginal operation will be signaled by different sounding pitches.

CMOS

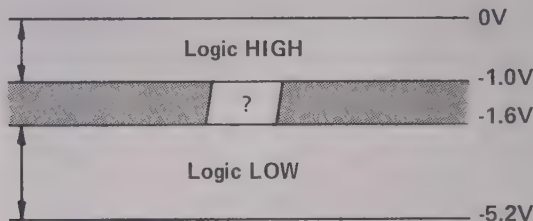


CMOS Logic Levels

Logic states for CMOS are defined as a percentage of supply voltage, as shown in the accompanying diagram. CMOS outputs, however, typically move to within 50mV of supply or ground when producing HIGHS and LOWS. Thus the typical HIGH and LOW sounds will fall in narrow, easily detected ranges. Faults or marginal conditions causing logic levels to drift far away from supply rails can be readily detected by their *VARI-PITCH* sound. Note that a

legitimate use of a CMOS output can pull it away from the supply rails. This typically occurs when the CMOS output is sourcing or sinking several mA, such as when driving transistors, LEDs, or other interface circuits.

ECL



ECL Logic Levels

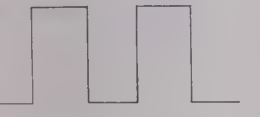
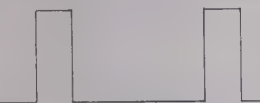
Emitter coupled logic systems usually operate between ground and -5.2 volts. When using the MX-333 LOGI-TRAK capability to probe ECL, the probe ground clip (or **COM** jack connection on the meter) should be connected to the -5.2 volt rail and not to system ground. The distinctive VARI-PITCH tones associated with logic HIGHS and LOWs can be easily obtained by first probing known, good logic levels. Different pitches signal conditions likely to be marginal or faulty.

OTHER LOGIC FAMILIES

Virtually any other current or future logic family may be probed with LOGI-TRAK and VARI-PITCH, providing the supply voltages are 20 volts or less. The basic technique is to probe known HIGHS and LOWs and learn their associated audio tones. Then if different tones are encountered, a glance at the MX-333 display will reveal the DC voltage present and allow you to judge if it is a likely fault condition or a consequence of the logic family and the way it is being applied. Basic knowledge of the logic family being probed is a prerequisite in this case.

SIGNATURE ANALYSIS

A simple form of signature analysis can be performed with LOGI-TRAK. The signature of a pulse train is that particular combination of logic HIGHS and LOWs which form the pulse train. The mixture of logic states will cause the pulse train to have a DC voltage level associated with it which may be different from the static logic levels. This DC voltage will produce a characteristic background pitch superimposed with the chirping VARI-PITCH sound present when pulses or logic transitions are detected by the LOGI-TRAK probe. With practice, the audio and/or voltage readout can yield information concerning the nature of the probed pulse train. The following examples will illustrate this principle. For clarity, consider a 5 volt CMOS system with logic levels near the supply rails.

Pulse Train	Display Readout	Audio
5V  0V Normally HIGH, Negative going narrow pulses	5:0 0	Chirp with high pitch background sound
5V  0V Normally LOW, Positive going narrow pulses	0:0 0	Chirp with low pitch background sound
5V  0V Square Wave	2:5 0	Chirp with intermediate pitch background sound
5V  0V Normally LOW, Positive going pulses, 20% duty cycle	1:0 0	Chirp with intermediate pitch background sound

Note that since "clean" pulses are rarely encountered in high speed logic, the attendant overshoots, ringing, etc. will affect the voltage readings somewhat.

INCREASING SENSITIVITY

The VARI-PITCH Audio threshold can be adjusted so that when used with LOGI-TRAK a TTL logic LOW (typically 0.2 volts) can be distinguished from ground. The adjustment will slightly increase the temperature sensitivity of the threshold, however, in most applications this will not be a problem. The setting may be readjusted any number of times without ill effects.

Refer to SOUND ADJ in the CALIBRATION AND MAINTENANCE Section. Perform the adjustment as outlined, except apply 0.00 volts to the V_{Ω} input, rather than 0.19 volts. Properly set, no sound will emanate with 0 volts applied, but a low frequency ticking sound will be heard at 0.2 volts, a typical TTL LOW voltage level.

SECTION VI

CALIBRATION AND MAINTENANCE

GENERAL

Your digital multimeter has been designed using the latest electronic technology. The unit has been built to provide long, troublefree operation.

Theory of operation and circuit description, along with the schematic and parts location diagrams, should allow troubleshooting of all but the most complex problems. If difficulties are encountered, Hickok maintains complete service facilities to provide timely repair of our products. Please refer to the Warranty page at the beginning of this manual for further details.

In addition to service information, a complete laboratory calibration procedure is presented for recalibration of your instrument should it be required.

THEORY OF OPERATION

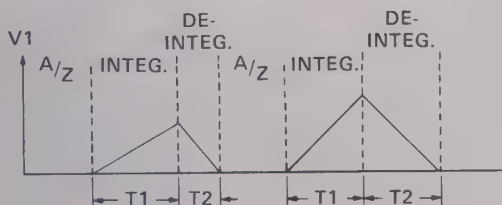
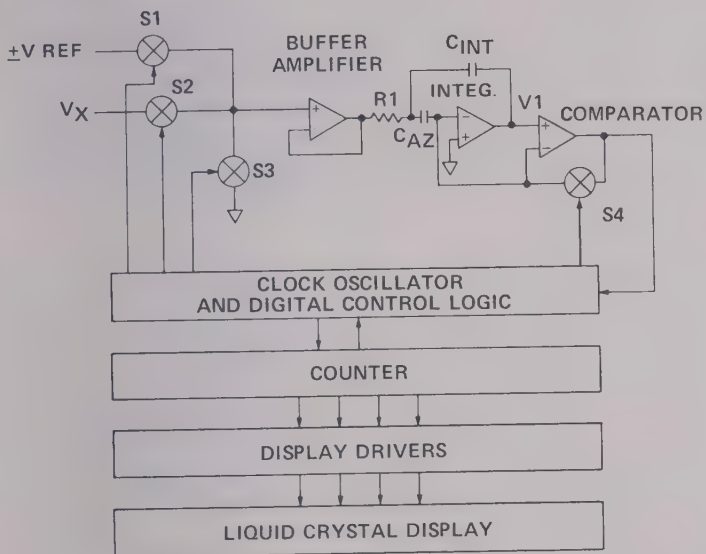
The instrument consists of two basic sections: the input signal conditioning circuitry, and the analog-to-digital converter. The purpose of the input circuitry is to take the parameter of interest (volts, ohms, or current) and convert it to a DC voltage whose level is proportional to the magnitude of the input. This DC voltage is then applied to the analog-to-digital (A/D) converter, which then converts the voltage to a numerical display. These circuits are discussed below. Also, refer to the schematic at the end of this manual.

ANALOG-TO-DIGITAL CONVERTER

All of the active electronics for the A/D conversion process are located in U103, a special low power LSI integrated circuit. The elements of this circuit are shown in the block diagram in figure 3.

The conversion process connects with an auto-zero (A/Z) phase. Analog switches S1 and S2 open to disconnect the input from any voltages. Switches S3 and S4 close. This circuit configuration is such that any offset voltage errors present in the buffer amplifier, integrator and comparator charge up the auto-zero capacitor (CAZ) to a compensating voltage which remains for the rest of the conversion cycle and corrects for the error voltages in the system.

The integration phase begins with S1, S3, and S4 opening, and S2 closing which connects the unknown input voltage (VX) to the system. Any non-zero voltage will cause the integrator output to ramp linearly. Figure 3 shows V1 ramping positive which implies that VX is negative. This ramping lasts for a fixed time interval, T1, determined by the internal clock, counter and digital control logic. As the diagram illustrates, the value of V1 at the end of T1 will vary according to the magnitude of VX.



	A/Z	INTEG.	DE-INTEG.
S1	O	O	X
S2	O	X	O
S3	X	O	O
S4	X	O	O

X = CLOSED
O = OPEN

Figure 3. Analog-to-Digital Converter

The final de-integrate phase starts with S2, S3, and S4 opening, and S1 closing which connects a fixed reference voltage, V_{REF} , into the system. The reference voltage is the opposite polarity of V_X . Thus the integrator will linearly ramp back towards zero volts. The internal digital counter begins counting from zero as soon as the reference is applied. When the integrator output, V_1 , reaches zero volts, the comparator output changes state abruptly, signaling the digital control circuitry that the conversion is over. The time it takes V_1 to reach zero volts (time interval T_2) is directly proportional to the magnitude of the original unknown voltage, V_X . This time interval, as recorded by the counter, is latched into a memory and then displayed on the liquid crystal readout.

The whole conversion cycle is repeated for every display update, about every 400ms. The reference voltage is derived from U102. During the auto-zero phase C111, the reference capacitor, is charged up to the reference voltage. The control logic examines the state of the comparator between T_1 and T_2 to determine the polarity of the input voltage. Then, via internal electronic switches, the reference capacitor is connected to the buffer amplifier either directly or "upside down" to provide the proper polarity voltage to return the integrator output to zero. The control logic also turns on the minus sign when appropriate and initiates the over-range indication for inputs exceeding full scale (1999 counts).

DC and AC Volts

Refer to figure 4. The basic range of the A/D converter is $\pm 200\text{mV}$. Any DC voltage in this area is applied directly to the A/D input. Higher voltages are reduced by R113, a 10 Megohm resistor divider network, which divides the input by a factor of 10, 100, 1000, or 10000 depending upon the range selected. If AC voltages are being measured, the divider output is directed to an active full-wave rectifier (U104 and associated components) which is calibrated to provide a DC output level equal to the RMS value of the AC input. An over-voltage protection circuit prevents excessive inputs from damaging R113.

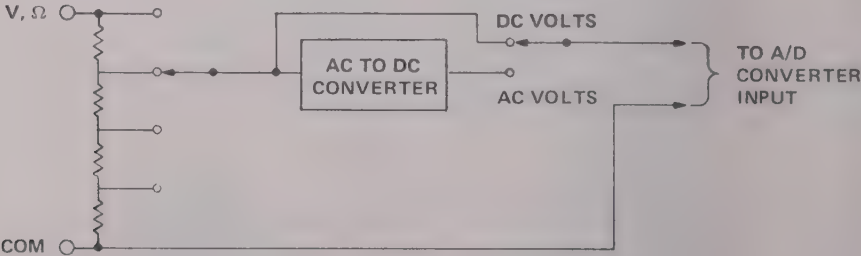


Figure 4. Voltage Measurement Input Circuit

DC and AC Current

Refer to figure 5. Both DC and AC current are measured in the same manner. The unknown current, I_x , passes through a fuse-diode shunt protection network and then through a current shunt resistor, R_s . The resulting voltage drop, $V_s = I_x R_s$, is measured by either the DC volts or the AC volts circuitry previously described to obtain the desired reading. The volts circuit operates with a fixed, 200mV full scale sensitivity. The current ranges are selected by changing R_s (R125, R126, R131, and R134).

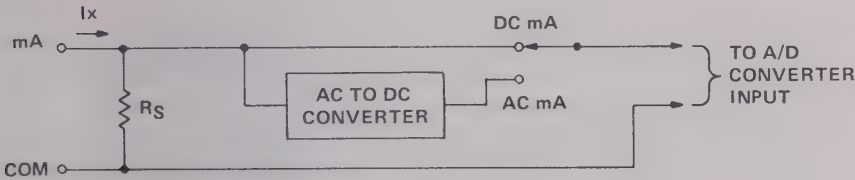


Figure 5. Current Measurement Input Circuit

Resistance

The ohms circuit is shown in figure 6. A ratio technique is used to measure resistance. A reference resistor, R_s (part of R113), is series connected between the unknown resistance being measured, R_x , and a voltage source. The voltage V_x developed across R_x is applied to the A/D converter input. The voltage V_s developed across the reference resistor is applied to the A/D converter reference input. (Note: when measuring volts or current the A/D reference input normally goes to a stable, fixed voltage source.) The ratio of R_x to R_s is the same as the ratio of V_x to V_s . Thus, since the value of R_s is known, the value of R_x can be determined by using the ability of the A/D converter to measure the ratio of V_x to V_s .

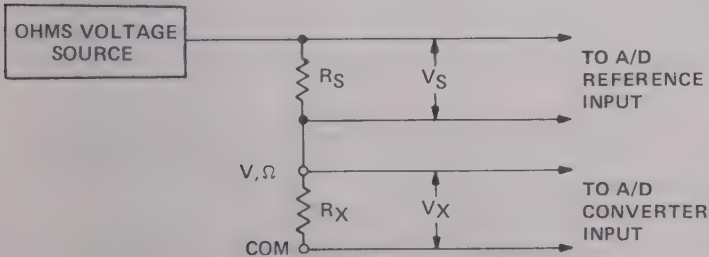


Figure 6. Resistance Measurement Circuit

VARI-PITCH

The VARI-PITCH sound circuit consists of a linear voltage controlled oscillator (VCO) preceded by a protected, high input impedance, non-linear amplifier.

The input amplifier consists of U201 and associated components. It is a non-inverting configuration which both amplifies and level shifts the zero to $\pm 200\text{mV}$ input so that it is compatible with the VCO input. Diode connected Q202 in the feedback loop non-linearizes the amplifier gain.

The VCO portion of VARI-PITCH is assembled with U202, Q201, and associated components. One half of U202 is connected as an integrator, while the other section is wired as an inverting comparator with hysteresis. Assume that the integrator has a positive output voltage level. This makes the comparator output low, turning Q201 off. A positive voltage at the integrator will cause it to ramp down, eventually switching the comparator and turning Q201 on. Because of the biasing of R204, R207, R210, and R217, the integrator will begin to ramp upwards. When the upper hysteresis point of the comparator is reached, it changes state turning Q201 off again and repeats the cycle. Thus, a triangle wave appears at the integrator output with a squarewave showing at the comparator output. The greater the integrator input voltage, the faster the output ramps and reaches the hysteresis set points and cycles, thereby increasing the frequency of the sound output.

LOGI-TRAK

Static voltages at the LOGI-TRAK input are divided down by R228 and R231 and directed to the DC volts measuring portion of the meter, including VARI-PITCH.

Pulse activity or logic level changes are passively detected with Schottky peak detectors CR204 and CR206. Comparator U204 amplifies any detected voltage and stores it with CR205 and C211 long enough to trigger a one-shot constructed from U206 and associated components. Using U205, the one shot gates the squarewave drive from the LCD display to energize the colon and via Q203 chops the VARI-PITCH input amplifier feedback loop to produce a chirping sound.

COMPLETE LAB CALIBRATION PROCEDURE

EQUIPMENT NEEDED

DC voltage standard with 0.01% accuracy - H.P. Model 740B, or equivalent.

Krohn-Hite 4200 Oscillator or equivalent.

Hickok Model DMS-3200 with DP-130 plug-in modified to accept 100% over-range, or Model 3400 or equivalent.

200 ohm, 1/4W, 5% resistor.

18.2 ohm precision resistor, 0.25% or better .

9 volt AC adapter - Hickok No. 1050-220 (Model RC-3).

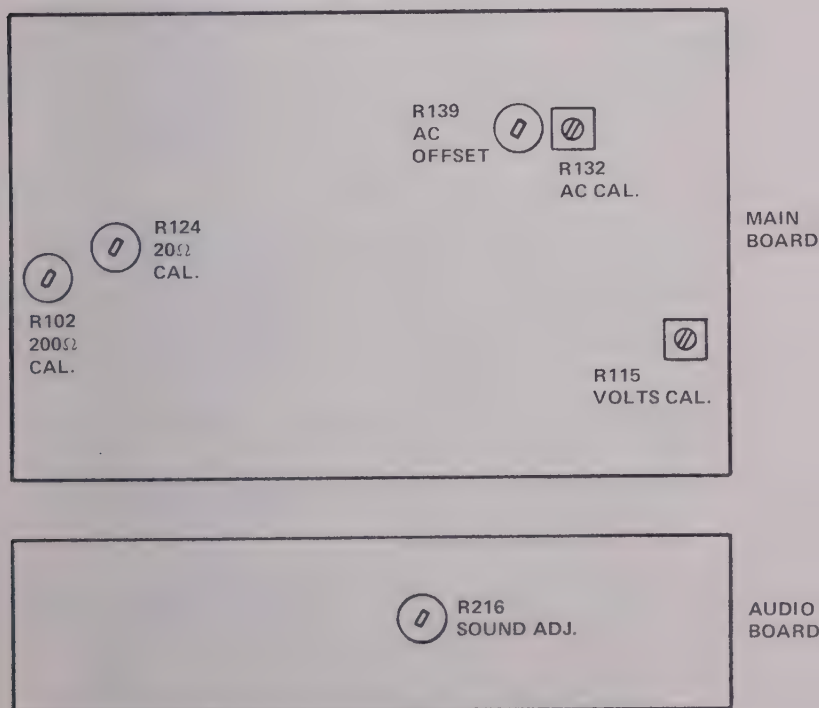
DMM with 2 volt DC range - Hickok LX-303 or equivalent.

Test leads.

DISASSEMBLY

All calibration adjustments are accessible upon removal of the top cover. To remove cover, unscrew the four fasteners located in the two top front and two bottom rear recesses, then lift the cover off straight up.

The adjustment locations are shown below.



FIRE-UP

NOTE

The VOLTS CAL adjustment (R115) must be performed first. The rest of the adjustment may be performed at any time in any order. If any adjustments require touching up, first make sure that R115 is properly adjusted.

The unit requires no warm-up. Ambient temperature should be between 23° and 27°C. Attach AC adapter to unit and push **POWER** switch in to activate unit.

DC VOLTS CAL

1. Push **DC** and **200mV** buttons. Connect high side of voltage standard to **V, Ω** jack. Connect low side of voltage standard to **COM** jack.
2. Set voltage standard to .1900 volts. Adjust R115 (VOLTS CAL) until meter reads 190.0mV ± 1 count. Disconnect voltage standard.

AC OFFSET

1. Make sure circuit shield is in place beneath PC board and connected to circuit common.
2. Short the **V, Ω** jack to the **COM** jack.
3. Push the **AC** button in. The **200mV** button should still be selected.
4. Connect a DC voltmeter set to the **1V** range from common to pin 7 of U104. (Note that the reading jumps around.) Set for best "0" reading by adjusting R139. Disconnect DC voltmeter.

AC CAL

1. Select **200mV** range. **AC** button should still be depressed. Connect sinewave generator between **V, Ω** and **COM** jacks. Monitor generator output with accurate AC DMM.
2. Set generator output to about 100.0mVrms at 100Hz. Adjust R132 (AC CAL) until display reads the same as the AC monitor DMM, ± 1 count.

200 Ω CAL

1. Select the **200 Ω** range and push the **OHMS** button. Connect a 200 Ω resistor between the **V, Ω** and **COM** jacks.
2. Monitor the DC voltage across the 200 Ω resistor, with an external DMM. The low side of the external DMM should go to the **COM** jack.
3. Adjust R120 (200 Ω CAL) until the voltage across the 200 Ω resistor is between 195 and 205mV.
4. Disconnect 200 Ω resistor and external DMM.

20 Ω CAL

1. Push the **SPECIAL FUNCTION** and **20 Ω** buttons. Connect test leads to the **mA**, **20 Ω** , and **COM** jacks.
2. Short the test leads together and adjust the front panel **20 Ω** null pot until the display is zeroed.
3. Connect an 18.5 Ω precision resistor between the test leads.
4. Adjust R124 (20 Ω CAL) until the display reads 18.50, ± 5 counts.
5. Disconnect precision resistor.

SOUND ADJ

1. Select the **20V** range and push the **DC** button. Display should be zeroed. Push the **AUDIO** button on. Connect .19 DC to the input.
2. Turn R216 (SOUND ADJ) until a ticking sound just disappears.

THIS COMPLETES THE CALIBRATION PROCEDURE

SECTION VII

CONVERSION TO RECHARGEABLE OPERATION

Any Hickok MX Series DMM may be converted to rechargeable operation by following the procedure given in this section. The following parts are required:

- 1 Hickok RC-5 AC Adapter/Recharger (cannot substitute)
- 1 Ni-Cad Rechargeable Battery - 9 volt transistor radio type
- 1 9.1 volt zener diode, 5%, 400mW
- 1 15 volt zener diode, 5%, 400mW
- 1 1.5K ohm resistor, 5%, 1/4W
- 1 510 ohm resistor, 5%, 1/4W

All of these items are collectively available from Hickok as part of the RC-6 Rechargeable Operation Conversion Kit. The industrial grade Ni-Cad battery supplied with the RC-6 kit offers longer life between charges and more recharges than commercial grade batteries generally available. The commercial grade, however, will work. The RC-5 AC Adapter/Recharger is available separately from Hickok.

WARNING

Rechargeable operation of the MX Series DMM must be with the RC-5 AC Adapter/Recharger only. Use of any other adapter may damage the instrument, the battery, or present a possible operator hazard.

Begin by removing the four screws holding the top and bottom covers of the unit together. Remove top cover. Lever the top of the front panel forward, then pull upward to free it from the bottom cover and pushbutton switches. Detach the main PC board from the bottom cover by removing the four screws located near the corners of the board.

Refer to the component placement drawing. With a sharp tool, carefully and completely sever the foil as indicated. Remove the 12 volt zener diode (CR111) as shown and replace it with the 9.1 volt zener, making sure the orientation of the new zener is the same as the one removed. Add the 15 volt zener (CRB), the 1.5K ohm resistor (RA) and the 510 ohm resistor (RB) as shown in the drawing. Reassemble the entire unit, taking care to make sure that no wires are pinched or broken, and that all parts are properly seated. Finally, install the rechargeable battery into the battery compartment. This completes the conversion procedure.

The MX unit will now operate in the following way:

1. Portable operation, using the internal battery, is the same as before except that operating time between recharges will be about 20% of a disposable alkaline battery.
2. The appearance of the "LO BAT" indicator means the unit requires a recharge.

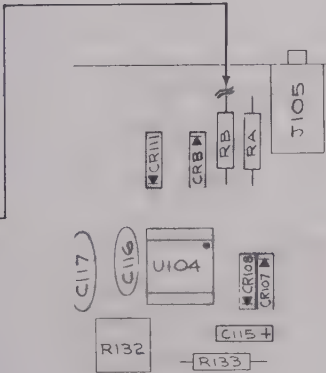
This should be done as soon as practical since the MX unit will operate properly only a short while once the indicator appears and possible deterioration of battery capacity may result if it remains discharged for a long time.

To recharge, connect the RC-5 AC Adapter/Recharger to a suitable power source, then attach the cord to the MX unit. The unit must be OFF to recharge the battery. Recommended recharge time is 14 to 16 hours. Turning the unit ON will stop the recharge operation and allow the unit to be powered from the RC-5 AC Adapter/Recharger alone.

Maximum battery life will result if it is "cycled," that is, charged fully, used until the "LO BAT" sign appears, then recharge fully again. If a replacement battery is ever required, suitable types are Gould type CS919, GE TRB895D1, or Varta TR 7/8, available from many industrial electronic parts distributors.

NOTE

Before installing RB, carefully and completely sever this PC foil.



SECTION VIII ACCESSORIES

A full line of accessories is available to complement the use of the digital multimeter. Here is a brief description of them and their use.



EARPHONE (MODEL EP-1)

The Model EP-1 Earphone accessory allows the VARI-PITCH function to be used in noisy environments, or where private listening is desired. The use of the earphone is completely safe since it is constructed from non-conductive materials. An acoustic tube principle is used to transmit the sound emanating from the front panel to the earpieces. With the earphone properly connected, most of the sound is directed through the earphone and only a slight amount of sound can be heard externally.

To use the earphones, take the fitting on the end of the tube leading from the headset and push it into the AUDIO opening using a single twist while pressing. Make sure the tube is well seated against the front panel. The small colored knob is a volume adjustment. To adjust for minimum sound turn the knob clockwise. For maximum sound turn the knob counterclockwise. The knob is multiturn and volume control occurs over several rotations.

To remove the earphones from the front panel, use a twisting pulling motion.

DELUXE CARRYING CASE (MODEL CC-4)

The Deluxe Carrying Case is a padded vinyl, zippered pouch which provides convenient storage and transport protection for the digital multimeter as well as having room for test leads, owners manual and some small accessories. The case has an adjustable shoulder strap for carrying convenience. The multimeter may be operated while in the case.

AC ADAPTER (MODEL RC-3 or RC-4)

The Model RC-3 AC Adapter is for powering the digital multimeter from the 115 volt AC line. The AC adapter plug fits into a recessed jack located on the rear panel of the unit. The battery is automatically disconnected when the AC adapter is used thus extending battery life. Input power to the RC-3 is 115V AC $\pm 10\%$, 50 to 60Hz. For use in European countries, the Model RC-4 is available. Its input power is 220V AC $\pm 10\%$, 50 to 60Hz with a European type plug.

WARNING

Line operation of the digital multimeter should be with the RC-3 or RC-4 Adapter only. Use of any other adapter may damage the instrument or present a possible operator hazard.

HIGH VOLTAGE PROBE (MODEL VP-40)

The digital multimeter can measure up to 40kV DC using the Model VP-40 High Voltage Probe. The probe divides all voltages by a factor of 100 as they enter the meter. This divide must be taken into account when reading the display. For example, if the display reads 250 on the **1000 volt** range, the actual voltage is $250 \times 100 = 25\text{kV}$. Use of the VP-40 probe increases the input resistance to 1,000 megohms on DC volts. The probe cannot be used for AC volts, resistance, or current measurements.

When making a high voltage measurement, plug the probe into the **V, Ω** jack and select the **1000 volt DC** range. Always connect the **COM** lead into the circuit first before using the probe. Disconnect the **COM** lead last, after removing the probe. ALWAYS use extreme care when measuring high voltages.

Specifications (When Used With MX Series Digital Multimeter)

Voltage Range:	40kV DC maximum input
Input Resistance:	1,000 megohms
Division Ratio:	100:1
Accuracy of Readings:	$\pm 1.2\% + 1$ digit, calibrated at 10kV
Voltage Coefficient:	-1ppm/volt

RF VOLTMETER PROBE (MODEL VP-14)

The digital multimeter can measure high frequency AC voltages in the 100kHz to 750MHz region using the Model VP-14 RF Voltmeter Probe. The probe provides a DC output that is calibrated to be the equivalent to the rms value of a sinewave input. Peak detection is utilized.

To use the probe, plug the red lead into the **V, Ω** jack, and plug the black lead into the **COM** jack. Select the DC volts function and pick the range

appropriate to the signal being measured. The ground connection on the probe itself should be as close as possible to the measured signal test point to obtain the greatest accuracy at high frequencies.

Specifications (When Used With MX Series Digital Multimeter)

Voltage Range:	0.25 to 50Vrms
Maximum DC input:	200V
Accuracy - 100kHz to 500MHz:	±1.1db (1Vrms sinewave)
100kHz to 750MHz:	±3.1db (1Vrms sinewave)
Input Capacity:	approx. 4.5pF

TEMPERATURE PROBE (TP-20C OR TP-20F)

The Model TP-20 Temperature Probe is an accessory which allows the digital multimeter to make precision temperature measurements.

The unit is available calibrated for reading in degrees Celsius over the range of -55° to +150°C (Model TP-20C) or for readings in degrees Fahrenheit over the range of -67° to +300°F (Model TP-20F). Either model is easily field connectable to the other temperature scale.

Surface, liquid, or gas temperature measurements may be easily made using the probe. The Model TP-20 is powered by a 9 volt transistor radio battery which will provide 500 hours of continuous operation. A battery test provision allows convenient checking of the battery condition.

The probe should be plugged into the multimeter with OUTPUT HI in the **V,Ω** jack and OUTPUT LOW in the **COM** jack. Select the **2V DC** range and turn the probe on. The display will indicate the temperature of the probe tip in degrees. Disregard the decimal point when making a reading. For example, the display will read .098 when the probe tip temperature is 98 degrees. A minus sign will appear for below zero temperatures.

Specifications (When Used With MX Series Digital Multimeter)

Temperature Range:	-55° to +150°C or -67° to +302°F		
Accuracy (with multimeter and plug-in housing at 20° to 30°C ambient):		°C	°F
	0° to 100°C	±1.6	±2.9
	-55° to 0°C	±2.8	±5.0
	+100° to 150°C	±2.9	±5.2
Settling Time (50°C step change):	12 sec. for stated accuracy (in immersion)		
Isolation Voltage:	200V DC or DC plus peak AC max.		

10:1 OSCILLOSCOPE PROBE (MODEL SP-7)

The Model SP-7 is a fixed X10 divider, 100MHz oscilloscope probe. It is used with the MX-333 LOGI-TRAK function, and acts as a high quality logic probe offering excellent sensitivity, minimal test circuit loading and outstanding overload capability. The SP-7 can also be used as probe for frequency counters since it offers high input impedance, low circuit capacitance loading, input protection, and noise attenuation.

Its usefulness as a wide bandwidth oscilloscope probe is enhanced with the accessories included with it. Provided are an insulating tip, a spring hook, a trimmer tool, a bnc adapter, and an i.c. tip. The probe and all accessories are supplied in a handy, zippered plastic carrying pouch.

Also available is the Model SP-6, similar to the SP-7, it offers in addition a switch selectable X1 or X10 probe divide.

Specifications (When Used With Instruments Having 1M Ω Inputs)

Bandwidth:	DC to 100MHz
Divide Ratio:	10 to 1 (fixed)
Risetime:	3.5 nanoseconds
Input Resistance:	10M Ω
Input Capacity:	13.5pF nominal (adjustable to compensate inputs having 10 to 60pF)
Working Voltage:	600V DC or DC plus peak AC
Cable Length:	6 feet

TACHOMETER ADAPTER (TA-104)

The TA-104 is an adapter which converts the multimeter to a highly accurate Tachometer/Dwell Meter for use on today's highly technical automotive engines.

To use the adapter, plug it into the **V, Ω** and **COM** jacks of the multimeter. Connect the red lead to +12V terminal of battery, the black lead to engine ground (car chassis or negative terminal of battery), and the yellow lead to distributor (-) terminal on ignition coil (or to special Tach Test terminal on some newer electronic ignition systems). Set CYL switch for 4, 6, or 8 cylinders depending upon engine, then select TACH or DWELL function.

Tach Readings

For 0-1999RPM, set the DMM to the **2V DC** range. Ignore the decimal point and read RPM directly. For example, if the display reads 1.250, the RPM is 1,250RPM.

For 1,999-5,000RPM, set the DMM to the **20V DC** range. Ignore the decimal point and multiply the reading by 10. For example, if the display reads 2.55 the RPM is $255 \times 10 = 2,500\text{RPM}$.

Dwell Angle Reading

Set the DMM to the **2V DC** range. Ignore the decimal point and read XX.X degrees. For example, if the display reads .450, it is read as a dwell angle of 45.0 degrees.

NOTE

When the yellow clip lead is completely disconnected or grounded, the reading will correspond to the maximum Dwell angle possible for an engine, which is 90° , 60° , or 45° for a 4, 6, and 8 cylinder engine respectively. This is normal and correct operation.

Specifications (When Used With MX Series Digital Multimeters)

TACHOMETER

Range:	0 to 5000RPM (4, 6, and 8 cylinder engines)
Output:	1mV per RPM
Resolution:	1RPM
Accuracy:	$\pm 6\text{RPM}$ at 600RPM $\pm 1.6\%$ of reading, 500 to 2000RPM $\pm 2.6\%$ of reading, 2000 to 5000RPM 15° to 35°C (add an additional 1% for each 10°C outside of 15° to 35°C)

DWELL

Range:	$0-90^\circ$
Output:	1mV per $.1^\circ$
Resolution:	$.1^\circ$
Accuracy (270RPM to 2,250RPM for 4, 6, or 8 cylinders):	$\pm 1.6\%$ of reading ($\pm .7^\circ$ at 45° reading) 15° to 35°C (add an additional 1% for each 10°C beyond 15° to 35°C)

GENERAL

Operating Voltage:	11-15V DC for stated accuracy, 20V DC absolute maximum
Temperature Range:	0 to 50°C operating -25° to 60°C storage

SECTION IX PARTS LIST

When ordering parts be sure to give the reference designation, description, and the Hickok part number as listed in the following table. Unless otherwise indicated in the DESCRIPTION column, parts listed are applicable to all models. Also include the model and serial number of the equipment. Minimum billing is \$50.00. Orders for less than \$50.00 will be accepted and shipped prepaid if accompanied by a check for the full amount plus \$3.50 postage and handling.

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
BT101		BATTERY: carbon zinc, 9 volt	2210-55
C101		CAPACITOR, FIXED, CERAMIC: disc type, . . . 33 pf, 10%, 100 volts	3110-254
C102		CAPACITOR, VARIABLE: piston trimmer, . . . 2-10 pf	3115-95
C103 thru C107 C108		CAPACITOR, FIXED, DIPPED MICA: value determined in production	
C109		CAPACITOR, FIXED, METALLIZED POLYCARBONATE: 0.1 μ f, 100 volts	3103-50
C110		CAPACITOR, FIXED, CERAMIC: disc type, . . . 0.1 μ f, 25 volts	3110-333
C111		CAPACITOR, FIXED, METALLIZED MYLAR: . . 0.047 μ f, 10%, 250 volts	3090-102
C112		Same as C110	
C113		CAPACITOR, FIXED, METALLIZED POLYCARBONATE: 0.47 μ f, 10%, 100 volts	3103-108
C114		CAPACITOR, FIXED, METALLIZED POLYCARBONATE: 0.22 μ f, 10%, 100 volts	3103-49
C115		CAPACITOR, FIXED, CERAMIC: disc type, . . . 100 pf	3111-516
C116		CAPACITOR, FIXED, BEAD TANTALUM: . . . 10 μ f, 25 volts	3085-480
C117		CAPACITOR, FIXED, CERAMIC: disc type, . . . 22 pf	3111-512
C118		Same as C109	
C119		CAPACITOR, FIXED, METALLIZED MYLAR: . . 0.033 μ f, 10%, 1600 volts	3090-128
C120		Not used	
C121		Not used	
C122		CAPACITOR, FIXED, ELECTROLYTIC: tantalum, 22 μ f, 15 volts	3085-491
C123		CAPACITOR, FIXED, CERAMIC: disc type, . . . 1500 pf	3111-523
C201		Same as C121	
		CAPACITOR, FIXED, CERAMIC: disc type, . . . 3300 pf	3111-525

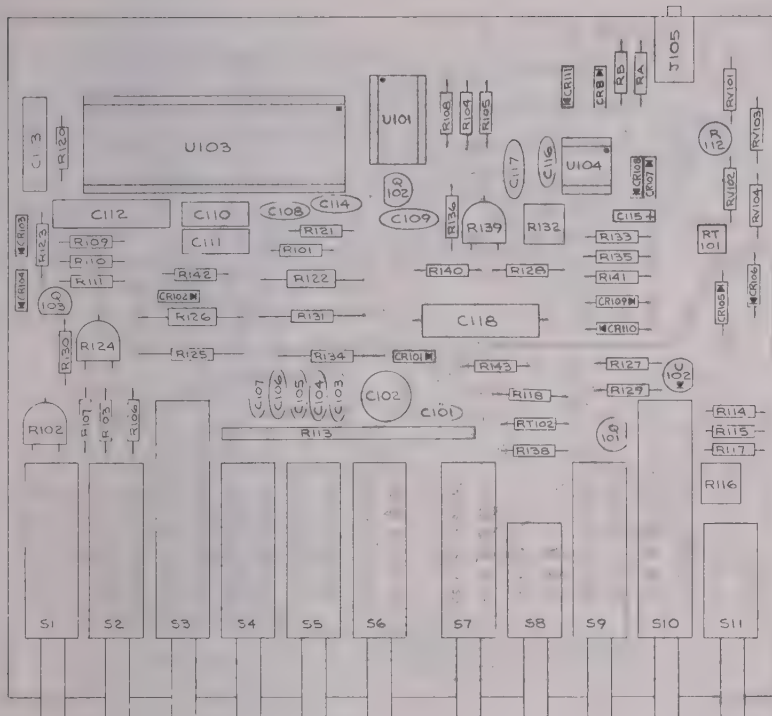
REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
C202		CAPACITOR, FIXED, METALLIZED MYLAR: 0.01 μ f, 10%, 250 volts	3090-101
C203		CAPACITOR, FIXED, ELECTROLYTIC: 47 μ f, -10% +50%, 25 volts	3085-449
C204		Same as C203	
C205		Same as C114	
C206		CAPACITOR, FIXED, ALUMINUM ELECTRO- LYTIC: 10 μ f, 25 volts	3085-448
C207		CAPACITOR, FIXED, CERAMIC: disc type, ... 0.01 μ f, 25 volts	3110-332
C208		Same as C109	
C209		Same as C114	
C210		CAPACITOR, FIXED, CERAMIC: disc type, ... 68 pf	3111-515
C211		Same as C114	
C212		Same as C109	
C213		CAPACITOR, FIXED, COMPOSITION: 1 pf, ... 10%, 500 volts	3116-11
CR101		SEMICONDUCTOR DEVICE: diode 1N5729B, ... $\pm$ 5%, 5.1 volts	3870-320
CR102		SEMICONDUCTOR DEVICE: diode 1N4148 or 1N914	3870-289
CR103		Not used	
CR104		Same as CR102	
CR105		SEMICONDUCTOR DEVICE: silicon diode 1N4001, 1 amp, 50 volt PIV	3870-229
CR106		Same as CR105	
CR107		Same as CR102	
thru			
CR110			
CR111		SEMICONDUCTOR DEVICE: diode 1N5738B, ... 400 MW, $\pm$ 5%, 12 volts	3870-323
CR201		Not used	
CR202		Same as CR102	
CR203		Not used	
CR204		SEMICONDUCTOR DEVICE: diode hot carrier 1N5711 or 5082-2800	3870-226
CR205		SEMICONDUCTOR DEVICE: 1N34A	3870-2
CR206		Same as CR204	
CR207		Same as CR102	
DS101		READOUT DEVICE: 3-1/2 digit liquid crystal, ... 0.5 inch digits, permanently attached mounting pins	18070-4
F101		FUSE: fast blow, 2 amp, 250 volts	6900-109
J101		JACK: machined	10300-138
J102		Same as J101	
thru			
J104			
J105		JACK: sub-miniature phone, PC mount, ... normally closed contacts	10300-116
J201		JACK: adapter, bnc connector	10300-136
Q101		TRANSISTOR: silicon 2N3904	20861-141
Q102		Same as Q101	

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
Q103 Q201 thru Q203 R101		TRANSISTOR: silicon 2N3906 Same as Q101	20861-412
R102		RESISTOR, FIXED, DEPOSITED CARBON: . . . 200K ohms, 5%, 1/4 watt	18470-204
R103		RESISTOR, VARIABLE: horizontal mounting, . 1K ohms, 20%	16925-819
R104		RESISTOR, FIXED, DEPOSITED CARBON: . . . 18K ohms, 5%, 1/4 watt	18470-183
R105		RESISTOR, FIXED, DEPOSITED CARBON: . . . 1 megohm, 5%, 1/4 watt	18470-105
R106		Same as R104	
R107		RESISTOR, FIXED, DEPOSITED CARBON: . . . 20K ohms, 5%, 1/4 watt	18470-203
R108		RESISTOR, FIXED, DEPOSITED CARBON: . . . 2.4K ohms, 5%, 1/4 watt	18470-242
R109		RESISTOR, FIXED, DEPOSITED CARBON: . . . 68K ohms, 5%, 1/4 watt	18470-683
R110		Same as R104	
R111		RESISTOR, FIXED, DEPOSITED CARBON: . . . 100K ohms, 5%, 1/4 watt	18470-104
R112		Same as R110	
R113 A-E		RESISTOR, FIXED, FUSIBLE WIRE WOUND: . 1K ohms, 10%, 2 watt	18575-779
R114		RESISTOR NETWORK: high voltage divider, . . . 10 megohms	16950-25
R115		RESISTOR, FIXED, DEPOSITED CARBON: . . . 2.7K ohms, 5%, 1/4 watt	18470-272
R116		RESISTOR, FIXED, METAL FILM: 12K ohms, . 1%, 1/4 watt	18555-276
R117		RESISTOR, VARIABLE: single turn, cermet, . . . 100 ohms, 10%	16925-792
R118		RESISTOR, FIXED, METAL FILM: 1.02K ohms, . 1%, 1/4 watt	18555-277
R119		RESISTOR, FIXED, DEPOSITED CARBON: . . . 2.4 megohms, 5%, 1/4 watt	18470-245
R120		RESISTOR, VARIABLE: linear taper, 5K ohms, . 20%	16925-928
R121		RESISTOR, FIXED, DEPOSITED CARBON: . . . 62K ohms, 5%, 1/4 watt	18470-623
R122		Same as R110	
R123		RESISTOR, FIXED, COMPOSITION: 1 megohm, 10%, 1 watt	18425-102
R124		RESISTOR, FIXED, DEPOSITED CARBON: . . . 51 ohms, 5%, 1/4 watt	18470-510
R125		RESISTOR, VARIABLE: horizontal mounting, . . 100 ohms, 20%	16925-837
R126		RESISTOR, FIXED, METAL FILM: 90 ohms, . . . 1%, 1/8 watt	18554-223
R127		RESISTOR, FIXED, WIRE WOUND: 9 ohms, . . . 1%, 3 watt	18575-678
		RESISTOR, FIXED, METAL FILM: 5.36K ohms, . 1%, 1/4 watt	18554-109

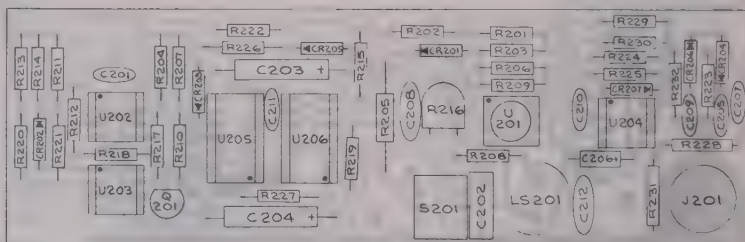
REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
R128		RESISTOR, FIXED, DEPOSITED CARBON: . . . 2.2 megohms, 5%, 1/4 watt	18470-225
R129		Same as R127	
R130		RESISTOR, FIXED, DEPOSITED CARBON: . . . 1.1K ohms, 5%, 1/4 watt	18470-112
R131		RESISTOR, FIXED, WIRE WOUND: 0.9 ohm, . 1%, 3 watt	18575-677
R132		RESISTOR, VARIABLE: single turn, cermet, . . . 200 ohms, 10%	16925-929
R133		RESISTOR, FIXED, METAL FILM: 4.75K ohms, . 1%, 1/4 watt	18555-237
R134		RESISTOR, FIXED, WIRE WOUND: 0.1 ohm, . 1%, 3 watt	18575-661
R135		Same as R110	
R136		RESISTOR, FIXED, DEPOSITED CARBON: . . . 2K ohms, 5%, 1/4 watt	18470-202
R137		RESISTOR, FIXED, WIRE WOUND: 0.01 ohm, . 1%, 5 watt	18575-774
R138		RESISTOR, FIXED, METAL FILM: 100 ohms, . 0.1%, 1/4 watt	18555-289
R139		RESISTOR, VARIABLE: horizontal mounting, . 500K ohms, 20%	16925-872
R140		RESISTOR, FIXED, DEPOSITED CARBON: . . . 10K ohms, 5%, 1/4 watt	18470-103
R141		RESISTOR, FIXED, DEPOSITED CARBON: . . . 33K ohms, 5%, 1/4 watt	18470-333
R142		Same as R110	
R143		RESISTOR, FIXED, DEPOSITED CARBON: . . . 330K ohms, 5%, 1/4 watt	18470-334
R144		RESISTOR, FIXED, DEPOSITED CARBON: . . . 1.3 megohms, 5%, 1/4 watt	18470-135
R145		RESISTOR, VARIABLE: vertical mounting, . . . 100K ohms, 20%	16925-838
R146		RESISTOR, FIXED, DEPOSITED CARBON: . . . 510 ohms, 5%, 1/4 watt	18470-511
R201		Same as R106	
R202		RESISTOR, FIXED, DEPOSITED CARBON: . . . 24K ohms, 5%, 1/4 watt	18470-243
R203		RESISTOR, FIXED, DEPOSITED CARBON: . . . 120K ohms, 5%, 1/4 watt	18470-124
R204		Same as R110	
R205		Same as R122	
R206		RESISTOR, FIXED, DEPOSITED CARBON: . . . 82K ohms, 5%, 1/4 watt	18470-823
R207		RESISTOR, FIXED, DEPOSITED CARBON: . . . 51K ohms, 5%, 1/4 watt	18470-513
R208		RESISTOR, FIXED, DEPOSITED CARBON: . . . 150 ohms, 5%, 1/4 watt	18470-151
R209		RESISTOR, FIXED, DEPOSITED CARBON: . . . 270K ohms, 5%, 1/4 watt	18470-274
R210		Same as R207	
R211		Same as R110	

REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
R212		Same as R140	
R213		Same as R110	
R214		Same as R110	
R215		RESISTOR, FIXED, METAL FILM: 20K ohms, 1%, 1/4 watt	18555-82
R216		Same as R102	
R217		Same as R207	
R218		Same as R140	
R219		RESISTOR, FIXED, METAL FILM: 24.3K ohms, 1%, 1/4 watt	18555-290
R220		RESISTOR, FIXED, METAL FILM: 15K ohms, . 1%, 1/4 watt	18554-73
R221		Same as R215	
R222		RESISTOR, FIXED, DEPOSITED CARBON: . . . 5.1K ohms, 5%, 1/4 watt	18470-512
R223		Same as R110	
R224		RESISTOR, FIXED, DEPOSITED CARBON: . . . 1K ohms, 5%, 1/4 watt	18470-102
R225		Same as R224	
R226		RESISTOR, FIXED, DEPOSITED CARBON: . . . 2 megohms, 5%, 1/4 watt	18470-205
R227		RESISTOR, FIXED, DEPOSITED CARBON: . . . 3 megohms, 5%, 1/4 watt	18470-305
R228		RESISTOR, FIXED, METAL FILM: 909K ohms, . 1%, 1/4 watt	18555-178
R229		Same as R110	
R230		Same as R104	
R231		RESISTOR, FIXED, METAL FILM: 100K ohms, . 1%, 1/4 watt	18555-37
R232		RESISTOR, FIXED, DEPOSITED CARBON: . . . 3.3K ohms, 5%, 1/4 watt	18470-332
RT101		RESISTOR: PTC, high voltage current limiter, . . . 1K ohms, 40% at 25°C positive temperature coefficient	18682-69
RT102		Same as RT101	
RV101 thru RV104		RESISTOR, VARISTOR: metal oxide, ... V430MA7B	18682-64
S1 thru S6		SWITCH: pushbutton, range, 6 station	19910-279
S7 thru S11		SWITCH: pushbutton, function, 5 station	19910-278
S201 A,B		SWITCH: pushbutton, perpendicular PC mount, dpdt, push-on, push-off	19910-280
U101		INTEGRATED CIRCUIT: quad 2-input exclusive OR gate CMOS 4070B	9800-226
U102		INTEGRATED CIRCUIT: voltage reference, . . . 1.23V $\pm$ 2.5%, 100 ppm/°C	9800-227
U103		INTEGRATED CIRCUIT: 3-1/2 digit single chip . A/D converter for liquid crystal display, ICL7106CPL	9800-209

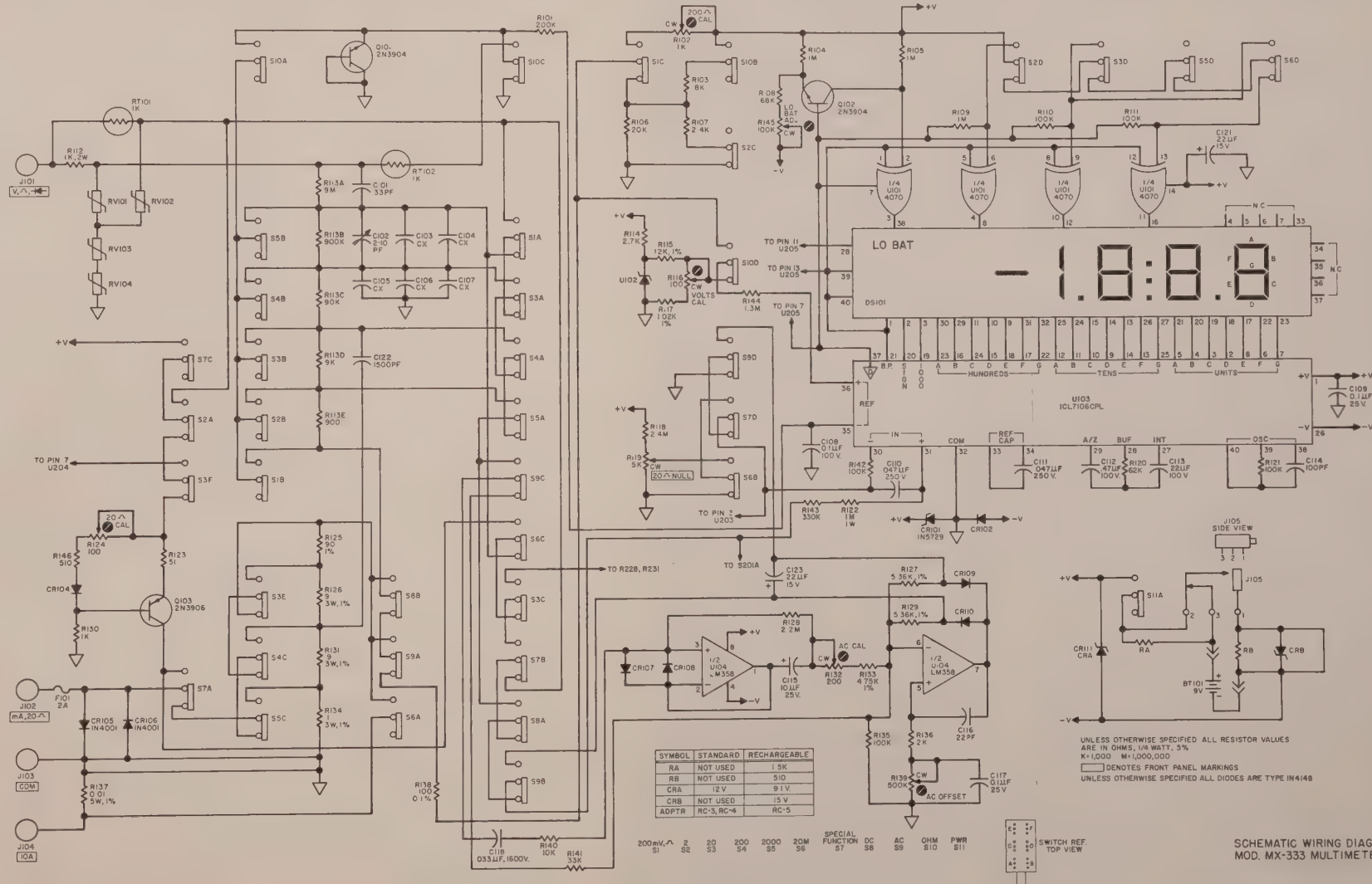
REF. DESIG.	NOTES	DESCRIPTION	HICKOK PART NO.
U104		INTEGRATED CIRCUIT: dual operational . . . amplifier, single supply, LM358N	9800-225
U201		INTEGRATED CIRCUIT: CMOS low power . . . operational amplifier, single supply, ICL7611DCPA	9800-245
U202		Same as U104	
U203		Same as U104	
U204		INTEGRATED CIRCUIT: LM301AN	9800-101
U205		Same as U101	
U206		INTEGRATED CIRCUIT: CMOS 4001 quad . . . 2-input positive NOR gate	9800-96
		LEAD ASSEMBLY: pair, (1) red, (1) black, s/w . mating standard alligator clip and black or red ins. boots	12450-488
		MISCELLANEOUS	
		ADAPTER ASSEMBLY: BNC	1050-228
		CASE: bottom, riveted	3126-554
		CASE ASSEMBLY: top	3126-570
		DOOR: battery compartment, molded	4450-33
		FASTENER: push-in, 1/8 shank, .300 diameter . head	6020-112
		KNOB: push-on, knurled, round	11505-266
		KNOB: special, molded pushbuttons	11505-301
		LEAD ASSEMBLY PAIR: (1) red, (1) black, . . . s/w mating standard alligator clip and black or red insulating boot	12450-488
		NAMEPLATE: front panel, upper	14100-958
		NAMEPLATE: front panel, lower	14100-959
		PANEL: front, machined	16025-687
		PANEL: rear, machined	16025-688
		PANEL ASSEMBLY: input jacks	16026-945
		SCREW: 8-32 x 1/4, plain 3/8 diameter head, natural nylon	19075-232
		SHIELD: formed	19155-688

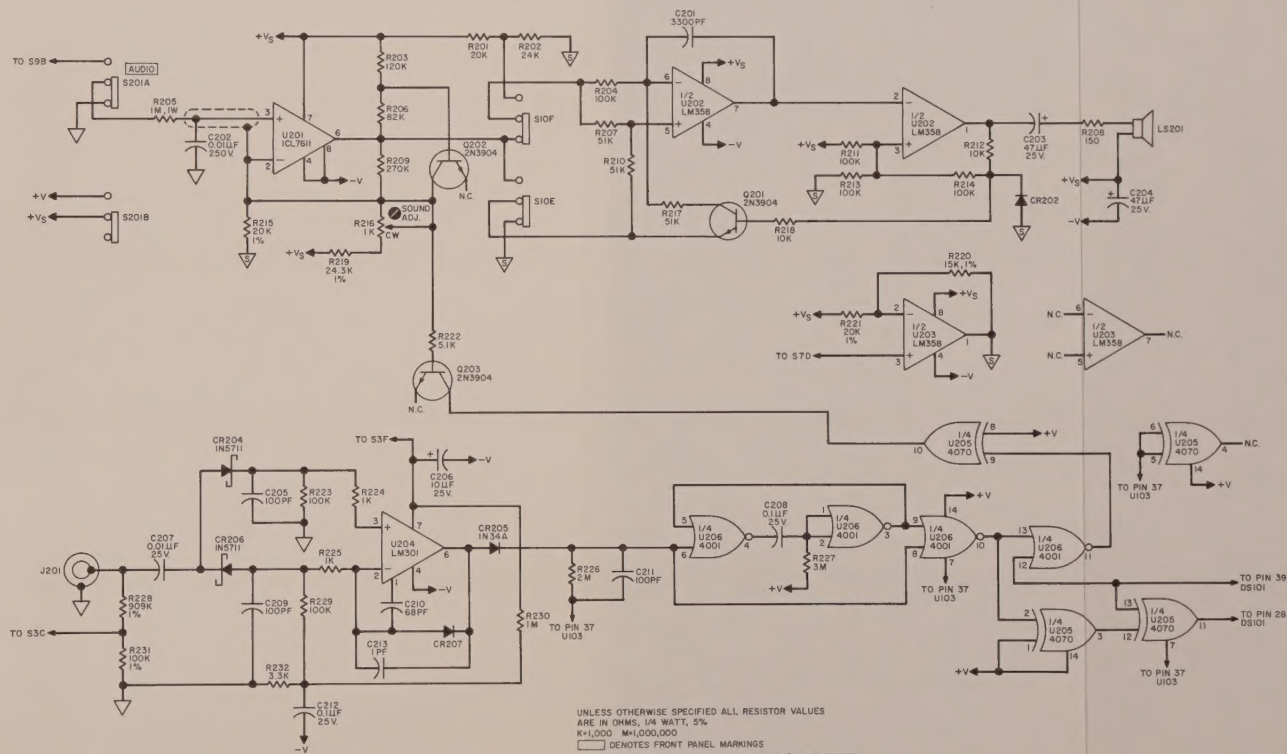


BOARD ASS'Y-MAIN



BOARD ASSY, AUDIO





SCHEMATIC WIRING DIAGRAM
MOD. MX-333 MULTIMETER



